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VECTOR SMART MAP LEVEL 1 - A NEW DMA PRODUCT

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ABSTRACT

The capability to produce Vector Smart Map Level 1 (VMap Level 1) is a new development within the Defense Mapping Agency (DMA). VMap Level 1 is a vector-based product currently derived from 1:250,000 cartographic source and designed to support Geographic Information System (GIS) applications with geographic data at medium resolution. This paper will discuss the purpose, data structure, and content of the VMap Level 1 data base. This paper will further describe the extraction, finishing, and distribution processes involved in the creation of VMap Level 1.

INTRODUCTION/PURPOSE

Digital mapping capabilities have flourished due to rapid technological advances in all areas of computer applications: computer hardware, software engineering, computer networking/communication, storage media, sensor development, and GIS's. In response to this digital data revolution and other changes in the defense environment, DMA has recognized a need to develop wide application, standard geographic digital data bases. These data bases or products will provide a wealth of information for future warriors and DMA customers, as well as potential civilian applications.

One of the new digital geographic data bases DMA has developed is VMap Level 1. VMap Level 1 is designed to support GIS applications with

geographic data at medium resolution. It represents the DMA Aerospace Center's first product data to include feature definition and attribution with rigorous topological definition. This data is designed to support today's advanced GIS query and analysis applications.

While this new product satisfies customer demands for digital products compatible with GIS applications, an equally important development was the creation of a new standard and exchange format named the Vector Product Format (VPF). This new standard facilitates the exchange of sophisticated digital vector products. The VPF is DMA's future standard for the distribution of digital geographic information to the Department of Defense.

The VPF is a spatial data format which provides standard encoding structures and data organization techniques for vector based data (e.g., VMap Level 1). The combination of the VPF and individual product specifications provides a versatile data set for modeling real world features in digital geographic data bases.

VPF has been coordinated with the Digital Geographic Information Exchange Standard (DIGEST) development efforts, thus it is compatible with this standard. These efforts are managed through the Digital Geographic Information Working Group (DGIWG), which allows for the international exchange of digital geographic information between national and multi-national systems.

In 1992, DMA contracted the development of a VMap Level 1 production capability. The initial design was based on a portion of the Digital Production System (DPS) Product Generation Segment (PG/S) hardware and software. In October, 1993, the VMap Level 1 "early data capture" (i.e., data extraction) capability was delivered to DMA. In October, 1994, the VMap Level 1 finishing capability was delivered to DMA. As part of the final production system design, commercial hardware, commercial software, and custom software were added to complete the end-to-end VMap Level 1 production and validation capabilities.

PRODUCT DESIGN/DATA STRUCTURE

The VMap Level 1 product design was based on the VPF data structure. The VPF provides a standard format, structure and organization for large geographic databases based on a georelational data model and is intended to support direct use. The VMap Level 1 product is defined by the Draft Military Specification Vector Smart Map Level 1 (MIL-V-89033) and the Military Standard Vector Product Format (MIL-STD-2407). Feature definition and attribution for VMap Level 1 is consistent with the Feature and Attribute Coding Catalog (FACC) found in DIGEST, Edition 1.2, Part 4.

The database represents the top of VPF's data hierarchy (See figure 1). For VMap Level 1, DMA has defined four databases. Each is based on one of the four Digital Chart of the World (DCW) libraries, thus providing worldwide product definition. A library is a collection of geographic, thematic vector data over a specified area of the globe, for both DCW and VMap Level 1. For DCW, each library represented one quarter of the globe.

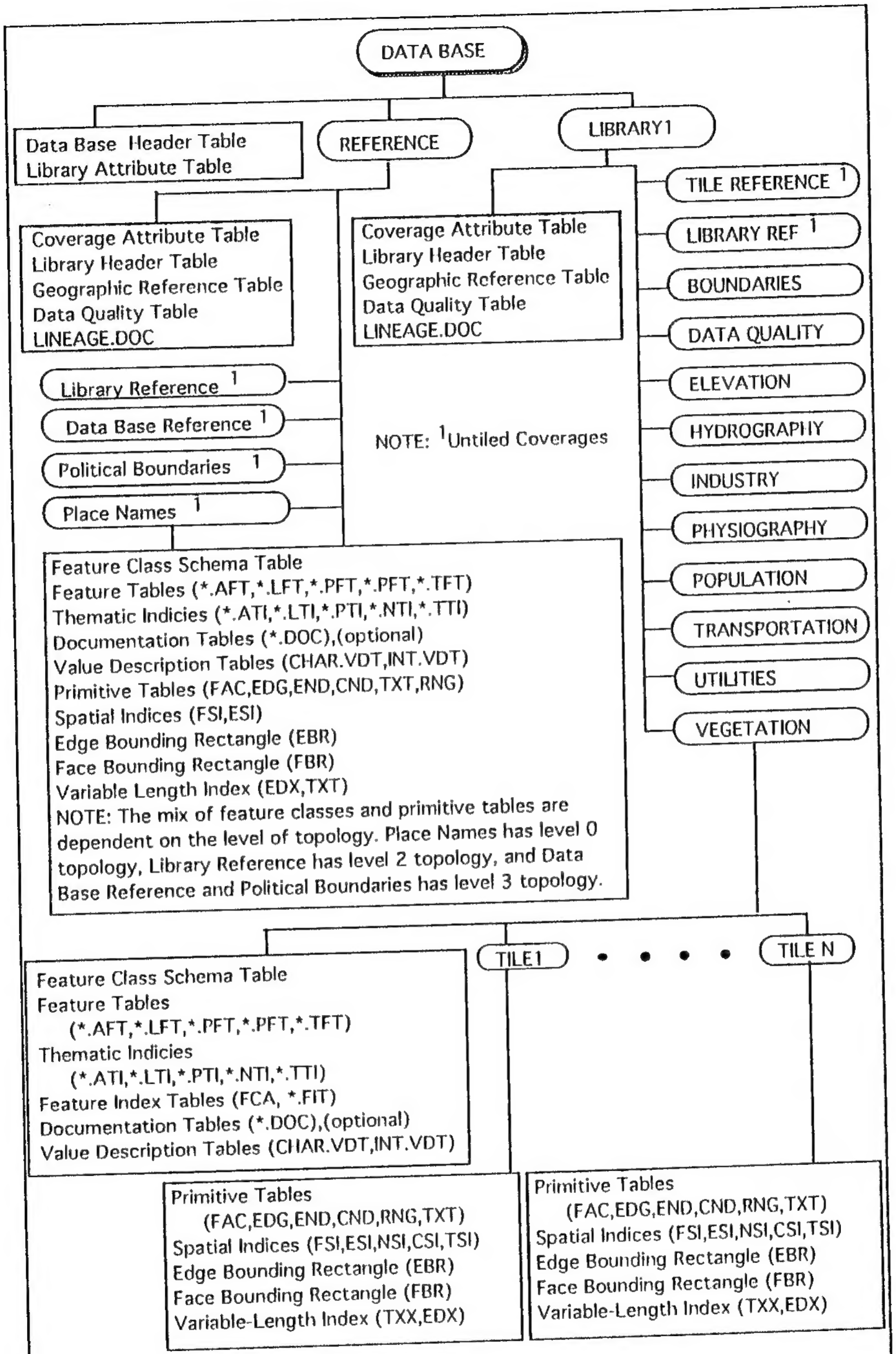

Fig. 1 VMap Level 1 Data Base Structure

For VMap Level 1, the library "footprint" is much smaller, and the feature resolution and attribution is denser and more detailed. Each database is broken into a series of libraries which, for VMap Level 1, have been defined

such that all data for a single library will fit on a single Compact Disc Read Only Memory (CD-ROM). Each library is broken into a series of thematic coverages, each with the same geographic extent as the parent library. It is at the coverage level that feature definition and topology exist in VPF structured data.

A reference library is provided on each VMap Level 1 CD-ROM which contains contains coverages (i.e., data base reference, library reference, political boundaries, and place names) which provides vector information which can be used to geographically orient the user to the area of the world the data set inhabits and the names and locations of the other libraries in the data base. Additionally, metadata is stored in tables at all levels in VMap Level 1. For example, data quality information, such as positional accuracy may be obtained for the product at the library level, and for specific features at the coverage level.

Each coverage contains a number of feature tables which identify those features found in the coverage's geographic area. Within each coverage, feature tables are created based on a specific type of primitive. For instance, features are modelled as areas, lines, points, nodes, or text. These divisions are called feature classes. Each record in a feature table contains the following: 1) a row identifier, 2) a FACC code identifying the feature, 3) a set of attributes which provide additional information about the feature, and 4) foreign keys to the primitive(s) which define the feature's shape and geographic location. The attributes available for each feature class are defined in the feature table header and are based on the VMap Level 1 military specification. Any coded attribute values are defined in Value Description Tables (VDT) at the coverage level.

Most VMap Level 1 thematic coverages have their primitives broken into tiles to reduce file sizes in the large geographic data sets. Tiles allow large data sets to be managed by computer hardware and software more effectively than a single, large spatial data set. Within a library, all tiled coverages use the same tiling scheme. When a coverage is tiled, each tile contains the complete topological definition for all primitives found in the tile. The VPF data structure provides cross-tile keys which link edge and face primitives across tile boundaries so that, within a coverage, the user is presented with a seamless topological extent.

Most VMap Level 1 thematic data coverages will be tiled, but reference coverages will not be tiled. The tiling scheme for various libraries will differ in their spatial extent and the number of tiles per library. In most cases, libraries will contain 30-50 tiles. The systematic tile structure is based upon the Geographic Reference System (GEOREF). Generally, a 1 degree by 1 degree tile will be used, but in high or low latitudes, other schemes will be employed. VMap Level 1 feature data is stored at a resolution of 0.02 arc-seconds.

VMap Level 1 recognizes three levels of topology; levels 0, 2, and 3. Topology describes the geometric relationships between points, nodes, edges, and faces. Level 0 topology stores point coordinates (intersections and nodes are not required). Level 2 topology stores start and end nodes, and left and right edges (nodes must break edges, edges must intersect, and edges meet at

nodes). Level 3 topology stores start and end nodes, left and right edges, and left and right faces (nodes must break edges, edges must intersect, and edges meet at nodes).

Topology is not supported between coverages. As such, a GIS is required if features in different coverages need to be combined for analysis. Also, the VMap Level 1 product is designed so that the relationship between records in feature tables and primitive tables is a 1:1 correspondence. This means that each feature points to only one primitive. However, the VPF structure allows compound and complex features to be represented in the event DMA customers require them in the future.

VMap LEVEL 1 CONTENT

The VMap Level 1 product describes real-world entities by modeling them as features. Feature locations (primitives), properties (attributes), and relationships are stored in tables, along with metadata which describes any pertinent information about the product source materials, the product itself, and the processes responsible for assembling the product.

VMap Level 1 features may be captured as points, nodes, lines, areas, or text. These five types of features are designated feature classes in VMap Level 1 and are described by a feature table and a geometric primitive table. Feature data are organized into thematic layers or coverages. Coverages can be classified as reference coverages or data coverages. The data coverages include most of the features commonly found on DMA produced Joint Operations Graphics (JOG). Within each coverage, some features may occur both as points and areas (depending on their size), such as built-up areas. They may also appear as both lines and areas, such as a linear river and an areal river. To assure consistency in DMA products, every effort has been made to coordinate data extraction procedures between DMA's DPS and the VPF/PS VMap Level 1. There are a total of ten thematic coverages in VMap Level 1, one for data quality and nine which make up the feature content. Figure 2 lists each of the feature coverages along with specific features found in the coverage.

VMap Level 1 data coverages are spatially co-registered to one another during data extraction and are referenced to the WGS84 and Mean Sea Level datums. Horizontal accuracy is expressed in ground distances as circular error at 90 percent probability and vertical accuracy is expressed in ground distances as linear error at 90 percent probability.

ARCHITECTURE AND SYSTEM OVERVIEW

The Vector Product Format Production System (VPF/PS) is the system DMA uses to produce VMap Level 1. It is composed of four production segments networked together to produce and revise topographic and hydrographic vector products (i.e., products distributed in VPF). To accommodate the production and revision of hydrographic vector products, topographic vector products, and other DMA hardcopy products, the VPF/PS segments perform specific tasks (see figure 3).

The specific tasks include the following functionality: (1) hardcopy or

softcopy data capture (Topographic Production Segment (TP/S), Nautical Production Segment (NP/S)), (2) data integration (TP/S, NP/S), (3) monoscopic revision (Revision Segment (R/S)), and (4) hardcopy product finishing (Hardcopy Product Finishing Segment (HF/S)) or softcopy product finishing (TP/S, NP/S). Currently, the primary tasks that DMA exercises for VMap Level 1 production are hardcopy data capture, data integration, and softcopy product finishing. These tasks are performed primarily on the Topographic Production Segment (TP/S).

<u>Boundaries</u>
Cairn
Control Point/Station
Fence
Wall
Coastline/Shoreline
Administrative Boundary
Armistice Line
Cease-Fire Line
Convention/Mandate Line
De Facto Boundary
International Date Line
Magnetic Disturbance Area
Administrative Area
Demilitarized Zone
Zone of Occupation

<u>Transportation</u>
Airport/Airfield
Control Tower
Mooring Mast
Airport Lighting
Vehicle Stopping Area /Rest Area
Runway
Bridge/Overpass/Viaduct
Ferry Crossing
Ford
Interchange
Snow Shed/Rock Shed
Tunnel
Aerial Cableway Lines /Ski Lift Line
Pier/Wharf/Quay
Railroad
Railroad Siding/Railroad Spur
Road
Cart Track
Trail
Tunnel
Railroad yard/Marshalling Yard

<u>Physiography</u>
Ice Peak/Nunatak
Rock Strata/Rock Formation
Cave
Mountain Pass
Geothermal Feature
Bluff/Cliff/Escarpment
Cut
Embankment/Fill
Ice Cliff
Crevice/Crevasse
Esker
Fault
Asphalt Lake
Ground Surface Element
Glacier
Snow Field/Ice Field
Salt Pan
Sebkha
Sand Dunes/Sand Hills
Moraine
Ice Shelf
Pack Ice
Polar Ice

<u>Industry</u>
Grain Bin/Silo
Grain Elevator
Mine/Quarry
Particle Accelerator
Chimney/Smokestack
Cooling Tower
Crane
Flare Pipe
Windmill
Processing/Treatment Plant
Rig/Superstructure
Well
Tank
Water Tower
Tower (non-communication)
Conveyor
Flume
Geophysical Prospecting Grid
Disposal Site/Waste Pile
Salt Evaporator
Settling Basin/Sludge Pond
Filtration/Aeration Beds
Fish/Hatchery/Fish Farm /Marine Farm

<u>Hydrography</u>
Aqueduct
Rock
Wreck
Water Intake Tower
Well (Water)
Spring/Water Hole
Cistern
Dam/Weir
Rapids
River/Stream Vanishing Point
Waterfall
Reef
Lock
Penstock
Breakwater/Groyne
Jetty
Seawall
Canal
Ditch
River/Stream
Foreshore
Island
Water (except inland)
Lagoon/Reef Pool
Land Subject to Inundation
Reservoir

<u>Vegetation</u>
Oasis
Cleared Way/Firebreak
Trees
Rice Field
Cropland
Grassland
Orchard/Plantation
Vineyard
Bog
Marsh/Swamp
Tundra

<u>Utilities</u>
Disk/Dish
Communication
Power Plant
Pumping Station
Pipeline/Pipe
Telephone Line /Telegraph Line

<u>Elevation</u>
Spot Elevation
Contour Line
Depth Contour
Void Collection Area

<u>Population</u>
Buildings
Built-Up Area
Fortification
Amusement Park Attraction
Ski Jump
Stadium/Amphitheater
Monument
Hut
Ruins
Race Track
Park
Settlement
Native Settlement

Fig. 2 VMap Level 1 Thematic Coverages and Features

The TP/S production software is composed of commercial-off-the-shelf (COTS) software and custom software. The majority of the custom software has been "built" on top of the commercial software baseline to leverage existing functionality. The data capture software is primary custom software whereas the integration and finishing software is primarily commercial. The production software is designed as a rules-based (or table driven) system. As such, software tables and rule sets drive "hardcoded" software applications and executables. The operating system of the TP/S is UNIX.

The TP/S hardware includes the following:
(1) high resolution, 27" dual screen cartographic workstations with digitizing surfaces,
(2) 19' single screen desktop workstations which are used primarily for system administration purposes,
(3) file servers for batch processing, storage, and control of peripheral drives,
(4) drum scanners,
(5) check plotters,
(6) thermal color printers,
(7) and numerous input/output peripherals.

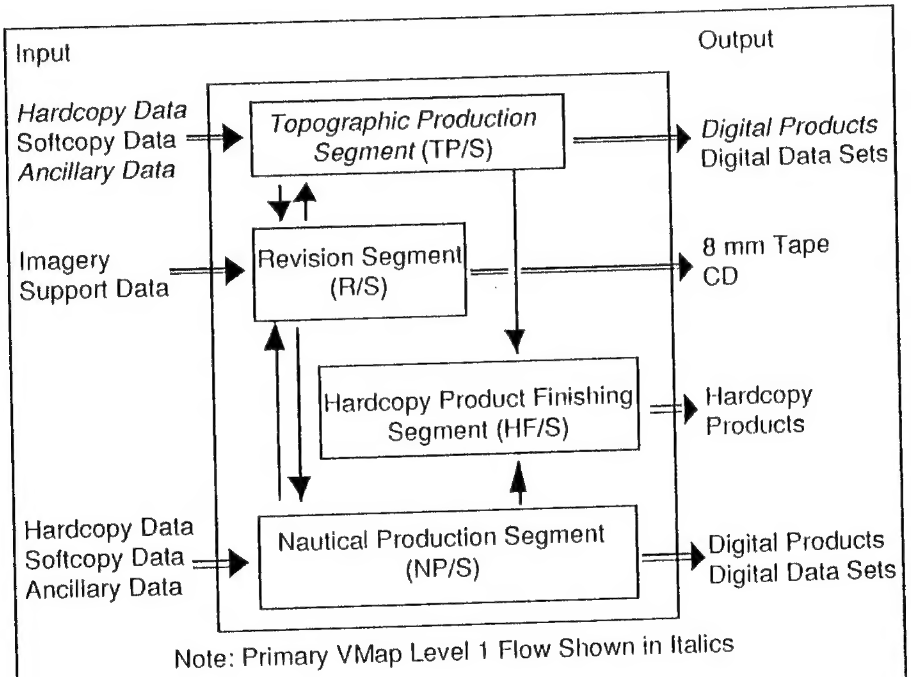

Fig. 3 Vector Product Format Production System

The entire VPF/PS hardware is connected to an Ethernet backbone which also provides connectivity to other DMA production systems.

EXTRACTION

The current path for VMap Level 1 production is to capture data from

DMA's JOG products. This will be the process description in the following extraction and finishing sections.

Prior to actual data extraction, some amount of source preparation and planning must take place. A source preparation package is assembled which contains all the necessary materials to complete a VMap Level 1 production assignment. The package will contain lithos, negatives, or positives (feature and combined separates), a control point printout, aeronautical update information, vertical obstruction data, a names overlay, and any special production assignment instructions.

Production planners examine the materials from the source package to verify completeness. Planners will document what VMap Level 1 features will be derived from what sources. A decision is made as to what sources will be scanned, digitized, or input via keyboard. Materials to be scanned may be enhanced or edited to enhance the conversion from raster to vector formats. Historical information (e.g., datum, ellipsoid, projection, currency and accuracy) is documented to populate applications software and metadata tables.

Once planners determine what sources are available and how it is to be used, system administrators use this information as input to drive production and data base management software. Graphic representations are created which describe all source and product information (e.g., source, tile, and library boundaries) needed for date extraction and finishing. Also, reference libraries and coverages are created which will later be translated to VPF in the finishing flow. Once the planners and data base administrators have completed their tasks, the production package is turned over to a production cartographer, who will perform data capture.

Generally, feature separate positives are scanned. The raster data can be displayed and edited if necessary. At this point, the raster data is ready for vectorization which can be done in a batch mode (automatic vectorization), interactive mode (semi-automatic vectorization or manual digitization), or a combination of the two. In most cases, "clean" raster data will be vectorized by batch mode. In this process, the raster data is converted into tagged edge vectors. These edge vectors are collapsed into centerlined features, recognized as specific features based on symbology training sets, and converted to an internal format. Any features failing the recognition process will be sent to a queue file for problem resolution.

Some feature separates may be more suited to the interactive mode of semi-automatic vectorization, such as dense contour or transportation separates. In semi-automatic vectorization, the raster data in a design file is automatically converted to vectors by line-following algorithms (based on recognition parameters) and a cartographer assists the software at decision points (e.g., line intersections). Once vectorization is complete, the design file(s) will be converted to an internal format which will be combined with the "batch" vectorized files. Due to data density, contour data is kept in a one internal format and feature data in another. If some feature separates require interactive heads-up or heads-down digitization (e.g., sparse separates), a separate internal format is created for this process, registered to the current

product area, and features are digitized.

Once all the raster data has been converted to vector data sets, the individual feature separate files will be sequentially transformed from the source projection and datum to the Universal Transverse Mercator (UTM) projection on the World Geodetic System 1984 (WGS84) datum. After the transformation, the files will be spatially registered to each other. Next, the files are vertically merged and combined to form a single, integrated internal format, with the exception of the contour internal format. Throughout the data capture process, "built in" quality assurance (QA) steps ensure the features, attributes, topology, geometry etc. are correct.

Assuming the data will not be revised or any hardcopy output is required, the data is prepared for the VMap Level 1 product finishing flow. The data is collected in the feature attribution coding system (FACS) in a Mark 90 internal format and is converted to a Mark 90 neutral file format at the completion of data extraction. Data integration converts this Mark 90 neutral file format to a commercial neutral file format, and then to a commercial internal format to prepare it for entry into the commercial finishing flow.

FINISHING

Up to this point, data from individual JOGS has been converted from raster data sets to vector data sets consisting of combined feature data files and contour data files. The boundaries of these files closely correspond to the original JOG input boundaries (but in many cases the data will be slightly shifted due to the transformation process). These files will now be clipped to tile boundaries. The clip process necessitates pieces of data from JOG's be combined to create full tiles. The pieces are sent to temporarily storage, where they will be called up and horizontally merged to create "full" tiles. Each full tile is now converted from a FACS coding scheme to a DIGEST FACC coding scheme. Tiles are edge-matched to ensure spatial compatibility between files. The control point printout coordinates are manually input and placed into the internal format and the coordinates are compared to derive product accuracy.

The FACC coding scheme is then mapped to a FACV internal coding scheme. This mapping is simply a reformating of the structure (i.e., features and attributes are identical) and prepares the data for conversion to the VPF directory structure. The combined features internal formats are segregated into separate internal formats which correspond to the coverages or themes. Next, the thematic, tiled internal formats are converted to the VPF format, one tile and one coverage at a time. The software then queries the eight thematic, surrounding tiles to populate triplet ids to ensure cross tile topology. Metadata information is populated for VMap Level 1 once the data has been converted to VPF.

Once the VMap Level 1 product has been created, it must be validated in order to ensure it conforms with the VPF structure and VMap Level 1 product specifications. The validation is a batch process which checks the topology, features and attributes, the table structure, and the directory structure. In the event that errors are detected, a FACC backup internal

format is reloaded into the system and corrected. The data must then be re-translated out to VPF and re-validated. There are tools available on the TP/S to correct small errors in VPF data.

After the final VMap Level 1 product has been validated, the data is reformatted to the ISO 9660 standard, and published on a CD-ROM for distribution. VMap Level 1 prototype data is distributed with VPFVIEW software. This software allows a user to display and query the data directly from the distribution media.

SUMMARY

The VMap Level 1 product and the VPF Production System have been designed to fulfill DMA's long term commitment to generate worldwide coverage of spatially attributed data. VMap Level 1 will support GIS applications for geographic data of medium resolution and is compatible with the DIGEST standard for the international exchange of digital geographic information.

The VMap Level 1 database will provide the modern warrior with a wealth of geographic information and will set new higher standards for the production of digital geographic information.

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